LOWER CARBONIFEROUS CONODONT BIOSTRATIGRAPHY OF NEW SOUTH WALES

by T. B. H. JENKINS

ABSTRACT. Based on collections totalling some thousands of specimens, the distribution of conodont elements in three main and several other subsidiary sections in the Carboniferous of New South Wales is summarized in terms of seven successive conodont faunas, six of which are regarded as indicating biostratigraphic zones. In upward succession these are individually characterized by (*a*) *Siphonodella* spp., (*b*) *Gnathodus punctatus*, (*c*) *Gnathodus semiglaber*, (*d*) *Gnathodus* sp. A, (*e*) *Scaliognathus anchoralis*, (*f*) *Pseudopolygnathus* cf. *nodomarginatus*, and (*g*) *Patrognathus* ? cf. *capricornis*.

Correlations with other Australian areas and with North American and European sections are briefly discussed on the basis of conodont distributions and comparison is made with previous intercontinental correlations of the New South Wales Carboniferous based on ammonoids. A conflict emerges between the conodont and ammonoid evidence on Viséan correlations.

ALTHOUGH the conodont biostratigraphy of the Carboniferous generally has reached a considerable degree of refinement little has been published of such studies for the system in New South Wales. More northerly Australian areas have received more attention in this connection, there being several recent publications dealing with Carboniferous conodonts from Queensland (Palmieri 1967, 1969; Druce 1970) and the Bonaparte Gulf Basin (Druce 1969), the latter greatly amplifying the initial reports by McWhae *et al.* (1958, p. 49) and Glenister (1960).

Two recent publications refer briefly to Carboniferous conodonts from N.S.W. Firstly, Rhodes *et al.* (1969, p. 60) commented on a fauna with pseudopolygnathids, *Gnathodus* cf. *punctatus* and *Bactrognathus* 'from the Berwick Formation of Australia'. (The formation name is undefined; the specimens came from the Carellan section, see below.) Secondly, Branagan *et al.* (1970, p. 129) recorded species of *Gnathodus*, *Polygnathus*, *Pseudopolygnathus*, *Neoprioniodus*, *Spathognathodus*, and *Hindeodella* from both of two conodont horizons in the Carboniferous sequence at Glenbawn dam in the Scone district of N.S.W. The lower horizon is recorded as carrying also species of *Siphonodella* and *Patrognathus* and the upper level as having forms belonging to *Dollymae* and *Ozarkodina*.

The foregoing N.S.W. conodont records are based on collections assembled over the last decade by the present writer and which now total some thousands of specimens. This communication summarizes the vertical distribution of conodont elements which emerges from a study of these collections and discusses these results in the light of what is known of coeval conodont distributions elsewhere. No attempt is made here to provide the fully detailed systematic analyses of the collections upon which the conclusions are based. Accounts of particular conodont faunas are in preparation for publication.

Major stratigraphical sections relevant to the present study are shown in text-fig. 1; a general account of the Carboniferous System in N.S.W. is to be found in Campbell *et al.* (1969). It may be noted in passing that limestones constitute only

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a very small part of the Carboniferous as it is developed in N.S.W. Clastics and volcanics form the bulk of the system, with glacial sediments appearing in the uppermost beds. Total thickness locally exceeds 6100 m, folding is moderately intense, and induration is such as effectively resists the disaggregation techniques usually employed for non-calcareous sediments. Consequently, conodont investigations in the N.S.W. Carboniferous have been limited by the distribution of calcareous rocks which seem to be confined to the lower part of the system.

This paper employs the nomenclature of disjunct conodonts, which has been used for many years in biostratigraphic work on the Carboniferous to the virtual exclusion of apparatus-based nomenclature. Many of the disjunct conodonts from the Carboniferous of N.S.W. are conspecific with the coeval forms elsewhere. Furthermore, their order of appearance and extinction in the investigated sections allows close comparisons with certain overseas sequences and the recognition of some conodont zones from northern continents.

SUCCESSION OF CONODONT FAUNAS

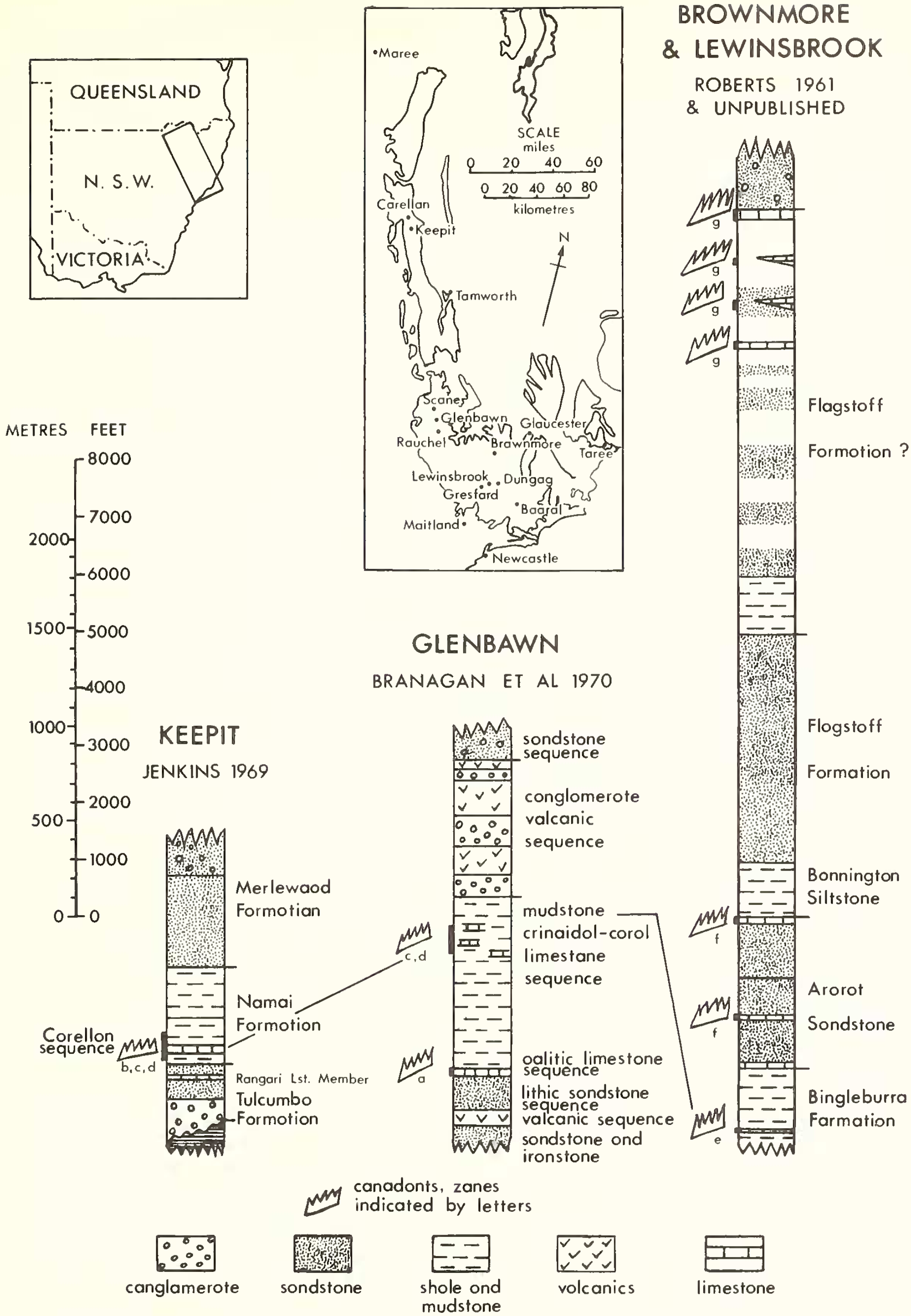
As has been pointed out in connection with the general sequence of invertebrate faunas (Campbell and Roberts 1969, p. 261), no single section or district exhibits the whole marine Carboniferous sequence of N.S.W. For the lower, intermittently calcareous, part of the sequence it is possible to propose a general succession of conodont faunas from detailed study of three main sections in the main Carboniferous belt of N.S.W.:

(i) The western limb of the Belvue Syncline about 1 km north-west of Carellan homestead (see text-fig. 1), where an unusually thick calcareous facies is developed low in the local Carboniferous section. This was reasonably assumed by Campbell and Engel (1963, p. 59) to be an expanded development of the persistent Rangari Limestone, but it has not proved possible yet to demonstrate the suggested equivalence. Two other relations are possible, (*a*) the Rangari is equivalent to the lower, more continuously calcareous part of the Carellan beds, and (*b*) the Rangari wholly underlies at an unknown depth the lowest of the beds exposed in the Carellan section. The latter possibility seems to the writer to be the most likely one at present, and the Keepit column in text-fig. 1 is drawn accordingly.

(ii) The Glenbawn dam area, where the sequence has been outlined by Branagan *et al.* (1970) and which has been included in a wider mapping project by Roberts and Oversby (in press) for the Bureau of Mineral Resources.

(iii) The Brownmore fault block, about 8 km north-west of Dungog, recently investigated by Dr. J. Roberts and his students at the University of New South Wales.

Supplementing these main sections are many shorter ones; two such minor sections, the first 1·5 km east of Gloucester (at the Stock Reserve) and the other about 5 km west of the town on the Walcha road, provided the first specimens of the important *Scaliognathus anchoralis* fauna, which has not been found equally well developed in any of the three main sections.



TEXT-FIG. 1. Locality map with outline of Carboniferous outcrops; conodont horizons in three principal stratigraphic columns for the main Carboniferous belt of New South Wales; conodont fauna (*a*) and proposed zones (*b*–*g*) indicated by letters keyed to text. Recent work by Roberts (pers. comm.) shows that near Brownmore all the strata between the Bonnington Siltstone and the unnamed conglomeratic sandstone belong to the Flagstaff Formation, which is 1800 m thick, i.e. about half the thickness depicted here.

Successive conodont faunas from these sections are characterized by the following species:

(top)

(*g*) *Patrognathus*? cf. *capricornis* (Druce)

(*f*) *Pseudopolygnathus* cf. *nodomarginatus* (E. R. Branson)

(*e*) *Scaliognathus anchoralis* Branson and Mehl

(*d*) *Gnathodus* sp. A

(*c*) *Gnathodus semiglaber* Bischoff

(*b*) *Gnathodus punctatus* (Cooper)

(*a*) *Siphonodella* spp.

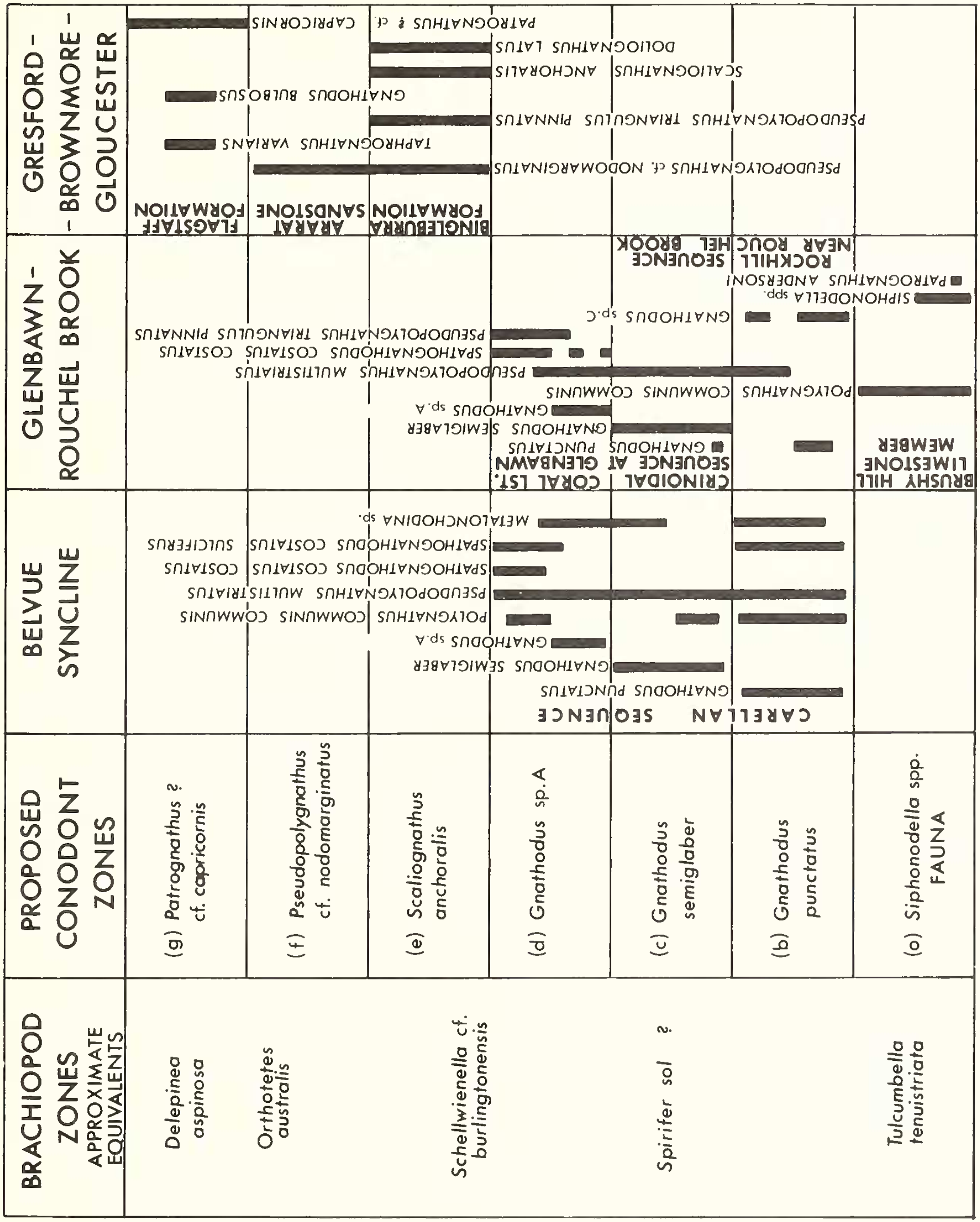
(base)

For a number of reasons it is proposed at present to regard the successive conodont faunas (*b*) to (*g*) as indicating informal biostratigraphic zones. The lowest fauna listed, characterized by *Siphonodella* spp., is distinct but insufficiently well-founded to be accorded zonal status; its known limits are determined by lithology. The next three faunas, (*b*) to (*d*), are both distinct in their platform elements and have accurately definable mutual boundaries in sections lacking detected signs of hiatus. The uppermost zone, with *Pa.*? cf. *capricornis*, is based on material from a few thin limestones disposed through about 600 m of section, within which is a narrower zone with a conodont fauna composed almost exclusively of *Gnathodus bulbosus* Thompson and *Taphrognathus varians* Branson and Mehl, which may be regarded therefore as a subzone.

(*a*) The *Siphonodella* spp. fauna is based on rather sparse conodonts recovered from the 23 m-thick oolite low in the Glenbawn sequence, to be named the Brushy Hill Limestone Member by Roberts and Oversby (in press), and best exposed in a large quarry immediately south-east of the dam wall. The few available siphonodellids (e.g. Pl. 119, fig. 10) are inadequate for specific allocation but some resemble late Kinderhookian forms. Also present are *Patrognathus andersoni* Klapper (Pl. 119, figs. 25–27), *Polygnathus communis communis* Branson and Mehl, *Pseudopolygnathus multistriatus* Mehl and Thomas, *Spathognathodus costatus costatus* (E. R. Branson), *Prioniodina prelaevipostica* Rhodes *et al.*, *Neoprioniodus* sp., *Ozarkodina* sp., and *Elictognathus*? sp.

(*b*) The *Gnathodus punctatus* Zone is based on conodonts from the lowest portion of the Carellan section and from exposures alongside the Aberdeen–Rouchel Brook road 0·4 km east of Rockhill homestead, where limy beds alternate irregularly with clastics through about 27 m of strata. The index species (Pl. 119, fig. 14) has also been found recently in the Gloucester district where it is reportedly accompanied in the lower part of its range by siphonodellids (pers. comm. D. T. Crane). Other elements of the fauna are *Pseudopolygnathus multistriatus*, *Bactrognathus hamatus* Branson and Mehl, *Polygnathus communis carina*, an unnamed subspecies of *P. communis* distinguished by faintly crenulate margins, and, at one locality, many specimens of *Gnathodus* sp. C (Pl. 119, fig. 28).

(*c*) The *Gnathodus semiglaber* fauna occurs in the lower, but not basal, part of the Carellan section, in the lower part of the 'crinoidal-coral limestone sequence' at Glenbawn dam, and at the top of the section near Rockhill, Rouchel Brook.



TEXT-FIG. 2. Proposed conodont zones for New South Wales and ranges of some stratigraphically significant conodont elements.

Accompanying the index gnathodid (Pl. 119, fig. 13) are the elements *Ps. multistriatus*, *Sp. costatus costatus*, *Sp. costatus sulciferus* (Branson and Mehl), *Sp. plumulus* cf. *shirleyae* Rhodes *et al.*, *Metalonchodina* sp., *P. communis communis* and the marginally crenulate subspecies of *communis* mentioned above.

The species name *semiglaber* is here used in the sense of recent North American authors, such as Thompson and Fellows (1970), which departs significantly from Bischoff's (1957) original concept. Likewise the naming of spathognathodid and pseudopolygnathid elements follows recent practice, especially that of Rhodes *et al.* (1969), although here again, as pointed out by Matthews and Naylor (1973, p. 364), there exists a case for systematic revision. Perhaps such revision should be integrated with a change from the prevailing element-based nomenclature to an apparatus-based nomenclature.

(*d*) The *Gnathodus* sp. A Zone occurs in the upper part of the Glenbawn 'crinoidal-coral limestone sequence' and in a short road section about 1·6 km east of Belah

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EXPLANATION OF PLATE 119

All figures are ×40 unretouched SEM images. Specimens are registered in the palaeontological collection catalogues of the Department of Geology and Geophysics, University of Sydney.

Figs. 1, 2, 4. *Gnathodus bulbosus* Thompson. 1, 2 oral and oblique oral views of SUP 22100. 4, oral view of SUP 22102; from limestones high in the Flagstaff Formation? in the Brownmore fault block, about 8 km north-west of Dungog, N.S.W.

Fig. 3. *Gnathodus texanus pseudosemiglaber* Thompson and Fellows. Oral view of SUP 22101; from upper part of Baywulla Formation at Baywulla Crossing, Yarroll Basin, Queensland.

Fig. 5. *Taphrognathus varians* Branson and Mehl. Oral view of SUP 22103; horizon and locality as for figs. 1, 2, 4.

Figs. 6–9. *Scaliognathus anchoralis* Branson and Mehl. 6, oral view of SUP 22104. 7–9, oral, aboral, and side views of SUP 22105; from unnamed formation about 7 km west of Dungog on new road to Gresford, N.S.W.

Fig. 10. *Siphonodella* sp. Oral view of SUP 22106; from 13·7 to 14·6 m below top of oolite (i.e. Brushy Hill Limestone Member) at Glenbawn Dam, Scone district, N.S.W.

Fig. 11. *Doliognathus latus* Branson and Mehl. Oral view of SUP 22107; from top of supposed Wootton Beds, Walcha road, about 5 km west of Gloucester, N.S.W.

Fig. 12. *Pseudopolygnathus triangulus pinnatus* Voges. Oral view of SUP 22108; horizon and locality as for fig. 11.

Fig. 13. *Gnathodus semiglaber* Bischoff. Oral view of SUP 22109 from 26·5 to 26·8 m above the exposed base of the Carellan sequence, Keepit district, N.S.W.

Fig. 14. *Gnathodus punctatus* (Cooper). Oral view of SUP 22110; from 4·0 to 4·3 m above the exposed base of the Carellan sequence, Keepit district, N.S.W.

Fig. 15. *Dollymae hassi* Voges. Oral view of SUP 22111; from unknown horizon within 'crinoidal-coral limestone sequence' at Glenbawn Dam, Scone district, N.S.W.

Figs. 16–18. *Polygnathus* sp. A. Oral, aboral, and side views of SUP 22112; locality as for figs. 6–9.

Figs. 19–21. *Gnathodus* sp. B. Aboral, side, and oral views of SUP 22113; locality as for figs. 6–9.

Fig. 22. *Gnathodus* sp. A. Oral view of SUP 22114; from high horizon in the 'crinoidal-coral limestone sequence' at Glenbawn Dam, Scone district, N.S.W.

Figs. 23, 24. *Pseudopolygnathus* cf. *nodomarginatus* (E. R. Branson). Aboral and oral views of SUP 22115; from Raglan Limestone at Raglan homestead, 8 km west of Booral, N.S.W.

Figs. 25–27. *Patrognathus andersoni* Klapper. Oral, oblique, and side views of SUP 22116; from 11·6 to 11·9 m below top of oolite (i.e. Brushy Hill Limestone Member) at Glenbawn Dam, Scone district, N.S.W.

Fig. 28. *Gnathodus* sp. C. Oral view of SUP 22117; from 24·0 to 24·3 m below top of limestone near Rockhill homestead, Rouchel, N.S.W.

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homestead on the Scone–Gundy road. The index gnathodid (Pl. 119, fig. 22) is distinguished by a broad nodose outer platform and an arcuate inner platform bearing transverse or slightly radiating ridgelets; it may be related to *Gn.* cf. *bilineatus* of Thompson 1967, p. 37, but is not identical with the species there illustrated (pl. 3, figs. 8, 10, 12, 17). Together with the gnathodid occur abundant *Spathognathodus costatus sulciferus*, *Sp. costatus costatus*, and *Ps. multistriatus*, which become dominant elements upwards as the gnathodids become rare or absent. In the upper part of the zone appears *Ps. triangulus pinnatus* Voges, *Dollymae* sp. (Pl. 119, fig. 15), and a new subspecies of *P. communis* distinguished by a row of small nodes flanking the anterior medial carina on one or both sides and linking with transverse carinae of the anterior platform. These distinctive forms could provide grounds for recognizing a subzone or separate zone if they are found to occur sufficiently abundantly.

(*e*) The *Scaliognathus anchoralis* Zone is known from five localities between Gresford and the coast at Taree, e.g. in the Taree Limestone at the railway cutting near the town; and in oolitic limestones crossing the Gresford–Dungog road 1·2 km east of its junction with the Gresford–Salisbury road. Field relations are such that at none of these localities can the zone's vertical continuity from an underlying conodont horizon be established and at only one locality (text-fig. 1, right-hand column), the second cited above, can the zone, there falling in the Bingleburra Formation, be placed in sequence with higher conodont-bearing formations. However, the position of the distinctive *anchoralis*-Zone conodonts in the general sequence of mid-Dinantian conodont faunas is sufficiently well established elsewhere to warrant the zonal sequence here given. Elements indicative of the zone include *Scaliognathus anchoralis* (Pl. 119, figs. 6–9), *Doliognathus latus* (Pl. 119, fig. 11), *Polygnathus* sp. A (Pl. 119, figs. 16–18), and *Gnathodus reversus* Thompson, Ford and Sweet, while *Ps. triangulus pinnatus* (Pl. 119, fig. 12) ranges up into the *anchoralis* Zone from the underlying zone, and *Ps.* cf. *nodomarginatus* and *Gnathodus* sp. B (Pl. 119, figs. 19–21) continue upwards above the range of *S. anchoralis*. These overlapping ranges thus support the partly inferred zonal position of the *anchoralis* Zone.

(*f*) The *Pseudopolygnathus* cf. *nodomarginatus* Zone is based on rather restricted faunas recovered from limestones within the Ararat Sandstone of the Lewinsbrook Syncline and about 8 km north-west of Gresford, and from the Raglan Limestone, outcropping near the homestead of that name 5 miles west of Booral. The commonest elements are intermediate in form between *Polygnathus* and *Pseudopolygnathus*, with elongate basal cavities and ribbed platforms which are usually asymmetrical in the manner of the latter genus. Such forms are widely reported under several names from mid-Dinantian strata and are here provisionally referred to *Ps.* cf. *nodomarginatus* (Pl. 119, figs. 23, 24). Near the base of the Ararat Sandstone *Gnathodus* sp. B occurs, and towards the top *Cavusgnathus* sp. appears.

(*g*) The *Patrognathus*? cf. *capricornis* Zone, based on the faunas from four thin limestones within the Flagstaff Formation? in the Brownmore fault block and from the Verulam Limestone near Gloucester, is characterized by the index fossil, accompanied in the lower part of its range by *Cavusgnathus* sp., and in the middle two limestones of Brownmore by *Gnathodus bulbosus* (Pl. 119, figs. 1, 2, 4), *Taphrognathus varians* (Pl. 119, fig. 5), and *Mestognathus* sp. I follow Klapper's (1971, p. 8) suggestion in referring Druce's species *capricornis*, with some reservations, to *Patrognathus*.

CORRELATION

Correlation with other Australian sequences

Conodonts from the Rockhampton Group of the northern Yarrol Basin (Druce 1970) suggest possible approximate Queensland equivalents for several N.S.W. formations: the Gudman Oolite (Qld) for the Glenbawn oolite (N.S.W.); the Gargoogie Oolite (Qld) for the Flagstaff Formation (N.S.W.); and the unnamed limestone of Druce's fig. 2 for the various formations carrying the *anchoralis* fauna in N.S.W. However, the published descriptions of the Yarrol Basin faunas are rather meagre and in no case can these possible correlations be regarded as established with either precision or certainty.

Correlation with the Bonaparte Gulf Basin is more firmly based, the conodonts having been monographed by Druce (1969). However, two factors operate against detailed biostratigraphic parallelism: firstly the absence from the northern faunas of the rich gnathodid component found in the N.S.W. faunas, and secondly, the termination of the calcareous sequences in such a manner as to provide no Viséan sequence in the Bonaparte Gulf Basin equivalent to the upper zones of N.S.W., and no known well-developed N.S.W. sequence equivalent to the lowest Carboniferous zones in the northern basin. The fauna of the Glenbawn oolite (Brushy Hill Limestone Member of Roberts and Oversby (in press)), with its rare siphonodellids, correlates with some part of the siphonodellid range from 91 to 274 m above the base of the Burt Range Formation; additional material is necessary to achieve closer correlation of the Glenbawn oolite.

The *Clydagnathus nodosus* Assemblage Zone of the northern basin cannot be recognized in the N.S.W. material but these eastern faunas do contain elements of the succeeding three zones recognized by Druce (1969). Included in the *Gn. punctatus* Zone in N.S.W. is *Spathognathodus anteposicornis* Scott; *Sp. costatus costatus* and *Sp. costatus sulciferus* become common in the upper part of the *Gn.* sp. A Zone. *Ps.* cf. *nodomarginatus* occurs in some of the succeeding *anchoralis* Zone faunas in N.S.W. and ranges upwards through the *Ps.* cf. *nodomarginatus* Zone. It seems likely that some part of this N.S.W. range includes the *Ps. nodomarginatus* Assemblage Zone of Druce and this raises the possibility that the *S. anchoralis* Zone may be represented in the Bonaparte Gulf Basin by sandstones above or within the upper part of the Septimus Limestone.

The rich conodont fauna of the Utting Calcarenite of the Bonaparte Gulf Basin cannot at present be matched in N.S.W. However, its *Taphrognathus* sp. element (Druce 1969, p. 139) has been named by Druce (1970, p. 102) as *T. capricornis* and is close to the form here termed *Pa.*? cf. *capricornis*, characteristic of the uppermost zone recognized in N.S.W.

Correlations with sequences outside Australia

The N.S.W. conodont sequence shows greater parallelism with certain sequences described from the northern continents than with those discussed above from northern areas of Australia. The Missouri conodont sequence for the Kinderhookian and Osagean described by Thompson (1967) and Thompson and Fellows (1970) is especially valuable in seeking to establish correlations with North America. On the other hand, some recent British results (Rhodes *et al.* 1969) for the lower and middle Avonian, based primarily on a succession of spathognathodid, polygnathid, and clydagnathid elements, are generally difficult to apply to the N.S.W. sequence in which the stratigraphically useful elements are mainly gnathodids and pseudopolygnathids. However, Butler's (1973) account of conodont sequences from the eastern Mendips, reveals considerable parallelism with the faunas here reported.

Three of the species names attached to the proposed N.S.W. conodont zones have previously been used, either alone or in conjunction, as name bearers for zones or subzones in Europe and North America:

Gnathodus punctatus, by Hass 1959, p. 367; by Thompson and Fellows 1970, p. 571;

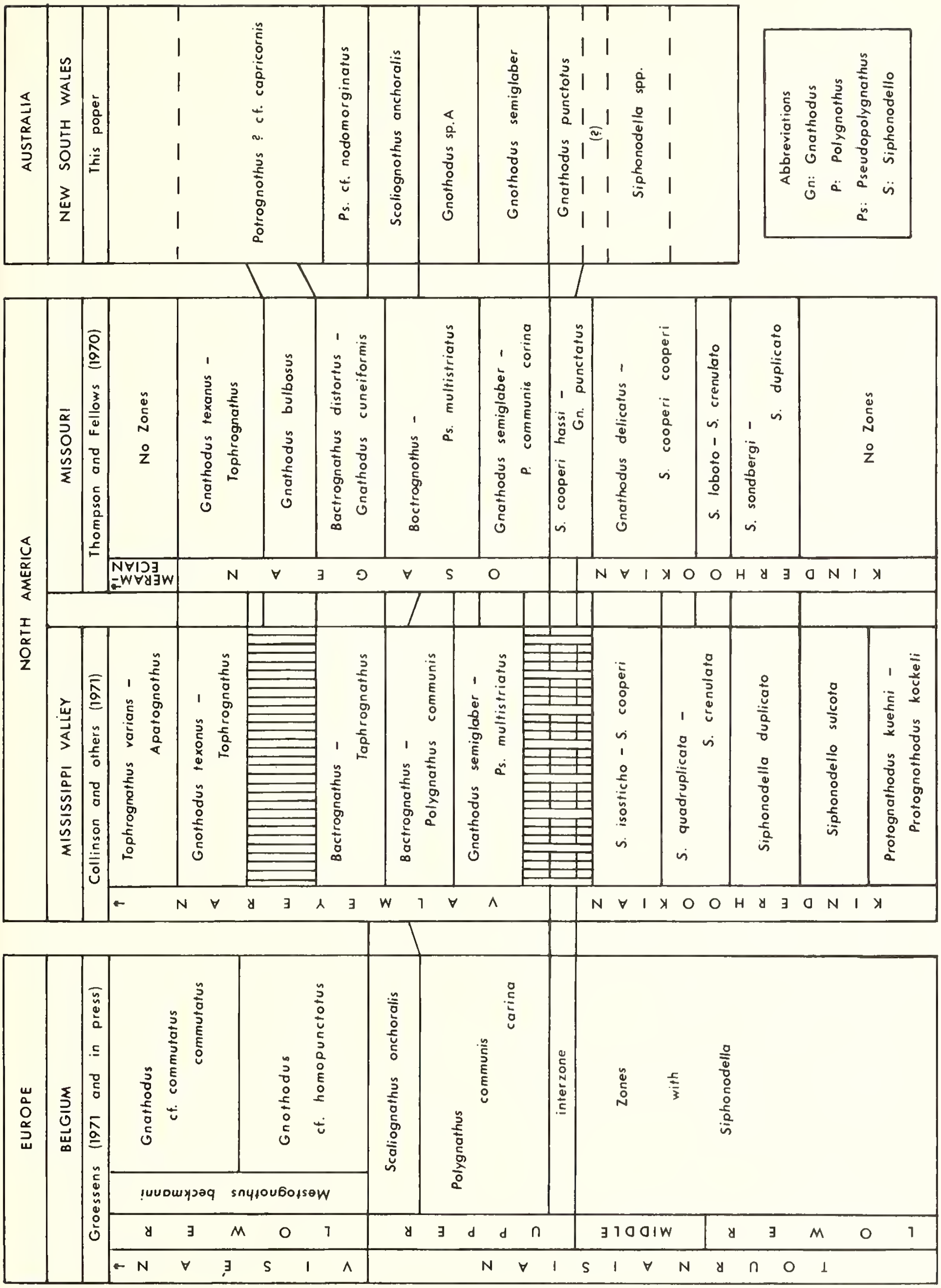
Gnathodus semiglaber, by Collinson *et al.* 1962, p. 22; Thompson 1967, p. 17; Thompson and Fellows 1970, p. 58; and

Scaliognathus anchoralis, by Bischoff 1957, p. 12; Voges 1959, p. 270; 1960, p. 216.

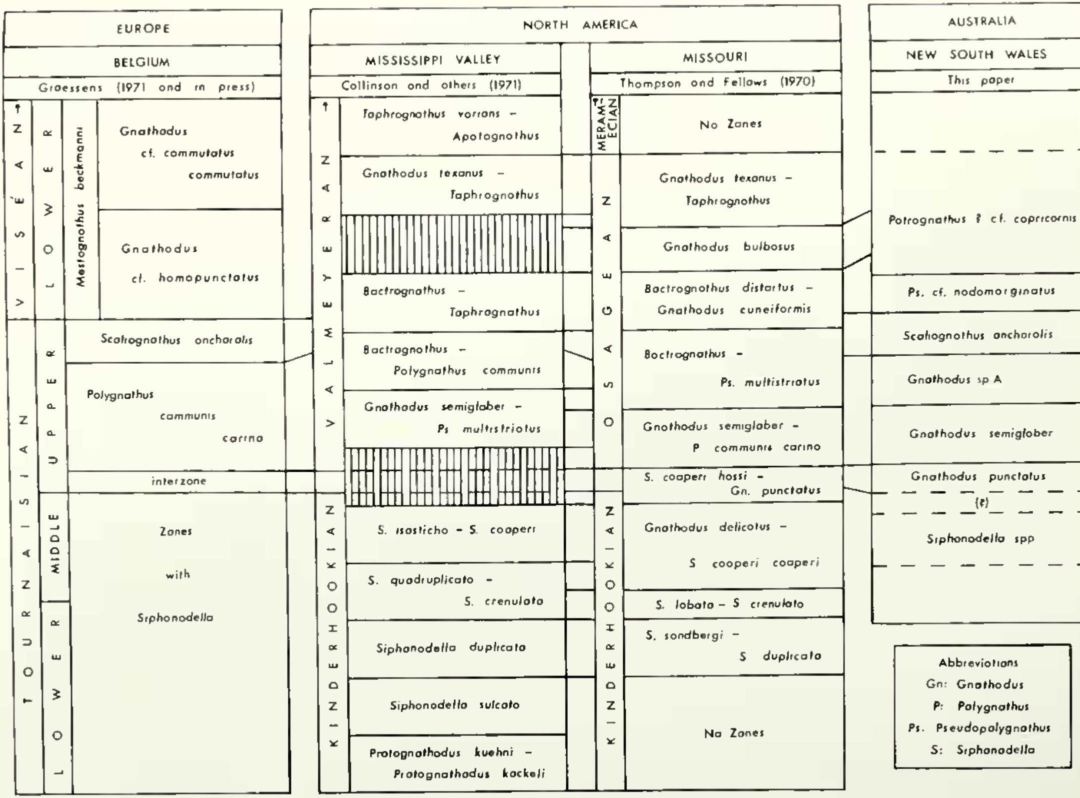
The last of these zones is very widely distributed, the *S. anchoralis* fauna having been recognized by one or more of its distinctive elements from Czechoslovakia (Zikmundova 1967) to Ireland (Hill 1971) and North Africa (Remack-Petitot 1960) and from the Mississippi Valley (Collinson *et al.* 1971) to New Mexico (Burton 1964) as well as from Queensland (Druce 1970) and N.S.W. (Branagan *et al.* 1970). It should be noted that Groessens (1971) and Groessens *et al.* (in press) have shown that the *anchoralis* fauna characterizes the upper part of the topmost division (i.e. upper Tn3c) of the Tournaisian stratotype, correcting the previous information in Conil *et al.* (1969) and, consequentially, lowering the cuIIγ horizon in terms of the Belgian equivalents. The *Scaliognathus anchoralis* Zone can thus, by direct correlation with the stratotype, be taken as indicating a topmost Tournaisian segment of the time scale.

The sequence of gnathodids forming the main basis for the *Gn. punctatus*, *Gn. semiglaber*, and *Gn.* sp. A zones in N.S.W. shows close parallelism with the Missouri sequence (Thompson and Fellows 1970, table 1). Replacement of *punctatus* by *semiglaber* and of *semiglaber* by *Gn.* cf. *bilineatus* or *Gn.* sp. A seems to be equally abrupt in Missouri and N.S.W. These vertical distributions are so close as to warrant equating the boundary between the *Gn. punctatus* and *Gn. semiglaber* zones in N.S.W. with the boundary between the *Siphonodella cooperi hassi–Gnathodus punctatus* Zone and the *Gnathodus semiglaber–Polygnathus communis carinus* Zone of Missouri.

Close parallelism between N.S.W. and Missouri gnathodid sequences contrasts with significant differences in the vertical distributions of other elements. In particular the N.S.W. sequence shows no sudden incoming of *Ps. multistriatus* at the top of the *semiglaber* Zone such as occurs at about this level in Missouri and the Mississippi Valley, for in N.S.W. such pseudopolygnathids continue through the gnathodid zones, with the chief change occurring at or near the top of the *Gn.* sp. A Zone, where elongate forms with attenuate platforms become dominant. *Polygnathus communis communis* becomes extinct in N.S.W. at about this level, although descendant forms continue into the *anchoralis* Zone. A common element of the latter zone in N.S.W. is *Doliognathus latus*, name giver for a Missouri subzone which correlates with the lower part of the *anchoralis* Zone in N.S.W. if the ranges indicated in Thompson 1967, p. 18 are accepted.



TEXT-FIG. 3. Comparison and correlation of conodont zones for the Tournaisian and Lower Viséan stages in Belgium, U.S.A., and New South Wales.



TEXT-FIG. 3. Comparison and correlation of conodont zones for the Tournaisian and Lower Viséan stages in Belgium, U.S.A., and New South Wales.

The *Ps*. cf. *nodomarginatus* Zone of N.S.W. is not readily matched in North American sequences but the name giver seems to be close to *Polygnathus mehli* Thompson, a minor component of the fauna in the Missouri Zone following the *latus* subzone, and which is recently reported to appear in abundance in a slightly modified form to distinguish a new subzone coinciding with the Cedar Fork Member of the Burlington Limestone in Iowa and the Mississippi Valley (Collinson *et al*. 1971, p. 379). In south-west Britain the Avonian is reported to have similar forms under the names *Ps. nodomarginatus* and *Polygnathus lacinatus* Huddle, the latter being used as name giver, alone or in combination, for three successive zones in the scheme of Rhodes *et al*. (1969).

Patrognathus? cf. *capricornis* seems to be known only from Australia but associated species have a wider distribution, notably *Taphrognathus varians* and *Gnathodus bulbosus*. In the Mississippi Valley sequence the former species enters sporadically in the uppermost subzone of the *Bactrognathus–Taphrognathus* Zone and persists up to the base of the *Apatognathus scalenus–Cavusgnathus* Zone (Collinson *et al*. 1971, p. 279). *Gn. bulbosus* is unknown from the Mississippi Valley sections but in Missouri it is the short ranged index for the *Gn. bulbosus* Zone of Thompson and Fellows (1970). There *T. varians* enters at the top of the *bulbosus* range. The North American ranges of the two species thus fall in the middle part of the Valmeyeran, in zones which Collinson *et al*. (1971, table 1), accepting Voges's (1960) tentative equating of the *anchoralis* Zone with the lower Viséan, correlate with the middle Viséan. As pointed out above, the *anchoralis* Zone has been found by Groessens's recent detailed work (1971, and in press) to lie within the Tn3c division, i.e. uppermost Tournaisian of the stratotype. The resulting recalibration of the conodont sequence with Belgian stratotypes requires the ranges of *Gn. bulbosus* and *T. varians* to be stated as lower Viséan, although neither species is presently known from Belgium. Recent work by Butler (1973) records *Gn. bulbosus* from the Mendips, near Bristol, England, where its range appears to fall within that of *S. anchoralis*.

These distributions are therefore consistently in favour of a mid-Dinantian correlation for the *Gn. bulbosus–T. varians* fauna, a lower Viséan level being indicated for these species by the position of *anchoralis* in the Belgian stratotype.

Comparison of intercontinental correlations based on ammonoids and conodonts

Previous extra-Australian correlations of the N.S.W. Dinantian have given weight to ammonoid occurrences, two of which can now be considered in context with the conodont faunas here reported.

From the Tulcumba Sandstone and its Rangari Limestone Member in the Belvue and Werrie Synclines, Campbell and Engel (1963) described a large fauna including the ammonoids *Muensteroceras* cf. *oweni* (Hall), *Protocanites lyoni* (Meek and Worthen), *Pr. australis* Delépine, *Prionoceras* (*Imitoceras*) *werriense* Campbell and Engel, and *Prionoceras* (*Imitoceras*) sp. One of several localities for the first three species listed above was given as 'one mile north-west of Croydon Homestead'. The name Croydon was an error for which the present writer is responsible, having supplied it to Campbell and Engel in locality details accompanying the ammonoid specimens in question; the name of the homestead is Carellan, the ammonoid source being in what is here called the Carellan sequence. The ammonoid horizon at Carellan lies in the lower half of the *Gn.* sp. A Zone. This zone, on comparison of the conodont data with that for the Belgian stratotypes, correlates with either Tn3a or, more probably, Tn3b, and in terms of the Mississippi Valley sequence corresponds to a pre-*pinnatus* part of the Burlington Limestone. This correlation of the Carellan ammonoid bed modifies the previous conclusion of Campbell and Engel (1963, p. 63) who found that both their ammonoids and brachiopods 'indicate a correlation with the Kinderhookian of North America, and the ammonoids suggest a correlation with cuI or cuIIα of the European succession' with 'a cuI age more probable'. The present conodont evidence points to the substitution of early Valmeyeran for Kinderhookian as the North American stage correlative of the Carellan ammonoid horizon, and strongly supports cuIIα in preference to CuI in the European standard, since Schmidts's (1925) cuIIα indices (*Pericyclus princeps* and *Muensteroceras complanatus*) derived from an isolated Belgian section now correlated with the lower part of the Calcaire de Calonne (Tn3c) (Delépine 1940, p. 7) and/or the uppermost Calcaire de Vaulx ($Tn3b_2$) (Mortelmans 1969, p. 39).

The non-sequential nature of the German ammonoid standard has been made clear in recent years (Paproth 1969, pp. 286–289; Matthews 1970*a*, pp. 115–117). A consequence is that the discrepancy between the proposed conodont-based correlation of the Carellan ammonoid bed with Tn3a or Tn3b and the original comparison with cuIIα (= Tn3c) made by Campbell and Engel is more apparent than real for between cuI and cuIIα there exists a substantial interval for which there are no presently available formal ammonoid zones, and in which the Carellan ammonoids may well belong. Another large hiatus in the German ammonoid 'standard' seemingly covers the whole of the Lower and Middle Viséan and the lowest part of the Upper Viséan (Weyer 1972, pp. 175–184; Groessens 1971). This latter gap is relevant to consideration of the ammonoid fauna from Trevallyn, near Gresford, N.S.W., first reported by Roberts (1961), who recorded the presence of *Prolecanites* sp. Subsequently, Roberts (1965*a*) figured and described his finds as did Brown *et al.* (1964) who discovered and named *Beyrichoceras trevallynense* from the same bed, then assigned to the Bingleburra Formation but now considered by Roberts (pers. comm.) to belong to the higher Bonnington Siltstone. The ammonoids were taken to indicate a cuIIIα–cuIIδ age in terms of the German standard, later restated as being 'as young as the European Viséan zone cuIIIα' (Campbell and Roberts 1969, p. 263). This correlation conflicts with the conodont evidence, for, regardless of whether the Trevallyn ammonoids belong to the Bingleburra Formation or the Bonnington Siltstone, their source underlies the Flagstaff Sandstone? with its *Gn. bulbosus–T. varians* fauna for which an early Viséan age is indicated (see above), in opposition to the late Viséan age deduced for the older ammonoids.

To consider briefly the ammonoid evidence, the two internal moulds identified and figured as *Prolecanites* sp. by Roberts (1965*a*, pp. 74–75, pl. 12, figs. 7–8, text-fig. 6) yielded only an incomplete suture, lacking the internal segment and the ventral lobe, so that generic allocation is not completely satisfactory. Again, the sutures of *Beyrichoceras trevallynensis* (Brown *et al.* 1964, fig. 6) have a character seemingly intermediate between *Muensteroceras* and *Beyrichoceras*. Recent Russian work on Lower Viséan ammonoids (e.g. Kusina 1971) has resulted in the recognition of several new genera, some with *Beyrichoceras*-like sutures (e.g. *Winchelloceras* Ruzhencev

1965, with the type species *Goniatites allei* Winchell = *Beyrichoceras allei* of Miller and Garner 1955) and others seemingly transitional with muensteroceratids (e.g. *Terektytes* Librovitch 1957). In reviewing the significance of Dinantian conodont correlations and ammonoid distributions Matthews (1970*b*, p. 1162, fig. 1) has inferred, without detailed documentation, that *Beyrichoceras* may have appeared in pre-*anchoralis* time.

These developments imply that the correlation of the Trevallyn ammonoids with cuIIδ or cuIIIα may no longer be as firmly based as when first proposed.

The discrepancy between ammonoid- and conodont-based correlations could be resolved by re-identification of the critical species or by revision of their time-ranges, or by showing that the conodonts had been reworked into late Viséan strata. To state the case for the conodonts one observes that the critical species (*Gn. bulbosus* and *T. varians*) are highly distinctive forms, unlikely to be confused with any other known species, and have time ranges established in well-documented overseas sections, as outlined above. The N.S.W. specimens show no detected signs of abrasion such as would be expected from reworking, and their occurrence in thin limestones within thick clastic sequences lacking known evidence of disconformity argues against reworking, as does the absence of admixture with forms indicating other horizons. Further, the conodonts in question occupy a distinct part of a well-characterized conodont sequence in N.S.W., and their position in that sequence is consistent with their position in extra-Australian sequences, allowing for minor differences of local time range. Again, *Gn. bulbosus* is claimed (Thompson and Fellows 1971, p. 89) to be a component of a phylogenetic progression of conodont elements (*Gn. bulbosus*–*Gn. texanus pseudosemiglaber*–*Gn. texanus texanus*) which, if true, enhances its significance as a time indicator, despite the absence from N.S.W. of the later members of the series. It is relevant here to note the occurrence of the second member, *Gn. texanus pseudosemiglaber* (Pl. 119, fig. 3) in the Baywulla Formation of the Yarroll Basin, Queensland, a formation correlated on its *Marginirugus barringtonensis* fauna with an horizon in N.S.W. well above that with *Gn. bulbosus*. It is relevant also to note that Butler (1973, text-figs. 2, 9) records the same order of appearance for these three gnathodids in the Mendip area of south-west England as was first reported from Missouri.

Finally, there is also the evidence of the brachiopods from Trevallyn, as stated by Roberts (1965*b*, p. 115) and Campbell and Roberts (1969, p. 263); they favour an earlier age than that indicated by the associated ammonoids, specific brachiopod comparisons being possible with forms from the Keokuk and Burlington limestones of the Mississippi Valley. These Osagean limestones are respectively within and mainly below the combined ranges of *Gn. bulbosus* and *T. varians* in North America. Brachiopod and conodont correlations are thus in substantial agreement.

Among the necessary corollaries of the proposed conodont correlation are great rapidity of sediment accumulation during mid-Dinantian times in the area north of Dungog and Gresford and the relative attenuation of the higher section which is available below the presently accepted base of the Permian for the later Viséan and Silesian (i.e. Upper Carboniferous). This raises the possibility of there being one or more undetected hiatuses in the higher Carboniferous section in the Dungog–Paterson area of N.S.W.